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Atlantic herring
Clupea harengus

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The Atlantic herring is a pelagic schooling clupeid ranging in the Northwest Atlantic from Greenland and Labrador south to Cape Hatteras (Bigelow and Schroeder 1953). In U.S. waters herring attain an overall maximum length and age of about 35 cm TL (14 inches) and 15 years, respectively (Anthony 1972). Male and female herring grow at about the same rate and become sexually mature by age 4 or 5.

Herring stock structure and migration patterns remain poorly understood (Anthony and Waring 1980, Graham et al. 1984, Sinclair and Iles 1985). Off the U.S. coast, large feeding and prespawning concentrations have been observed from May through August along the fringes of Georges Bank (prior to the late 70's) and off southwest Nova Scotia (Sinclair and Iles 1985). Spawning occurs between August and October from Nantucket Shoals and Jeffreys Ledge northward to coastal Maine (Anthony and Waring 1980, Graham et al. 1984, Sinclair and Iles 1985). In November, herring migrate to overwintering areas from the New York Bight to Cape Hatteras (Anthony and Waring 1980, Sinclair and Iles 1985).

Scales were originally used to determine the age of herring. During the 1960's, however, many researchers began using otoliths routinely due to problems with scale loss during handling (Hunt et al. 1973) and difficulty with interpretation of herring scales from waters south of Cape Breton (Huntsman 1919, Lea 1919, International Passamaquoddy Fisheries Board 1960). Otolith nucleii have been found to be quite useful in discriminating between races that spawn at different times during the year (spring vs. autumn spawners) (Einarsson 1951).

Although use of otoliths to age young herring from the Gulf of Maine was validated by Watson (1964), difficulties with the ageing of older fish persisted through the mid 1970's, with poor levels of age agreement between scales and otoliths (Messieh and Tibbo 1970), and between otolith age readings by different age readers (e.g., Parsons and Winters 1972). More recently, however, improvements in techniques, informal otolith exchanges, documentation of anomalous zones on otoliths (Dery and Chenoweth 1979) and indirect validation through the tracking of prominent year-classes through the fishery have resulted in substantial improvement in the accuracy and consistency of age interpretations.

Herring otoliths have been prepared for ageing in several ways. Otoliths have been stored in small vials prior to examination (Lissner 1925); or an adhesive, such as ethylene dichloride, has been used to bond each pair at the bottom of small depressions in black plastic trays (Watson 1965). Otoliths were then covered by distilled water or ethyl alcohol for examination. Another method, currently preferred by most age readers, is to embed the otoliths in a plastic resin after the method of Raitt (1961). At the Woods Hole Laboratory, herring otoliths are embedded in Permount resin (distal otolith surface up) on black molded plastic trays, and viewed under reflected light at a magnification of 15-20×. Since hyaline zones are not strongly developed on herring otoliths, the use of a plastic resin affords a much higher level of opaque/hyaline zone contrast than is possible by simple immersion in ethyl alcohol. It is especially useful in interpreting the outer zones on the otoliths close to the margin, which may be thin, split, or poorly defined. Difficulty with interpretation of the otolith margin was cited by Messieh and Tibbo (1970) as a major impediment to the use of otoliths for ageing Atlantic herring. At that time, most researchers used ethyl alcohol rather than plastic resin as a viewing medium (Hunt et al. 1973).

Herring otoliths from the Georges Bank and Gulf of Maine region exhibit a prominent hyaline core area immediately surrounding the nucleus, the outer edge of which is interpreted as the first annulus if hyaline zones are counted as annuli (Hunt et al. 1973) (Fig. 1). This zone is typically overgrown with calcium on the otoliths of older fish. Backcalculation results in an average fish size of 4-5 cm when this zone is completely formed (Dery, unpub. data). Bigelow and Schroeder (1953) and Boyar et al. (1973) found that herring in this size range occur in the Gulf of Maine during the spring months. Therefore, the hyaline core area is formed over a period of approximately 6 months, assuming that herring are spawned during the early autumn months. Few, if any, otoliths of herring from the Gulf of Maine or Georges Bank exhibit a tiny hyaline core area surrounded by opaque material that would indicate that they were spring-spawned fish. Scattergood (1952) and Bigelow and Schroeder (1953) reported no evidence of spring spawners in the Gulf of Maine area in the early 1950's; subsequent reports and observations tend to support the continuance of this pattern (Watson 1964, Anthony and Waring 1980, Kornfield et al. 1982).

The hyaline annulus on the otoliths of age-2 fish and older generally begins to form in October and is completed by the following March or April (Messieh 1974, Dery and Chenoweth 1979) (Fig. 2). However, opaque edge may persist on otoliths of age-5 fish or older in the late autumn months (Fig. 3) and may resume later in the spring relative to younger fish (Fig. 4). By convention, a birthdate of 1 January is used; the hyaline zone forming on the edge of the otolith is interpreted as an annulus whether or not it is complete. Time of annulus formation can vary in some years, however. The formation of opaque edge during winter has been characteristic of several year-classes (Dery and Chenoweth 1979). Checks can also cause confusion with edge interpretation. Therefore, correct evaluation of the type of edge formed on the otolith, and its meaning in terms of the growth of the fish, is an important aspect of herring age interpretation.

False annuli, formed during the first summer of the first full year of growth, are typical anomalies encountered on herring otoliths and may be especially characteristic of particular year-classes. Normally, false annuli are weak or incompletely formed hyaline zones, and because of their proximity to the nucleus, are not readily confused with the second annulus (Fig. 5). However, false annuli may occasionally appear as strong, continuous zones often associated with a wide summer growth increment (Fig. 1). These zones can be readily confused with annuli, and therefore the resulting age interpretation should be compared with that of fish of similar sizes.

The second annulus, which is sometimes a split, diffuse zone (Figs. 6 and 7) tends to be somewhat overgrown with calcium on otoliths of older fish, especially on the rostrum (Figs. 3 and 4). Subsequent to the second annulus, checks are normally formed during the second, third, and fourth summers corresponding to the prespawning period. These checks are especially prominent on the posterior and lateral part of the otoliths and are weak or not evident on the rostrum (Figs. 2, 4, and 8). Therefore, the rostrum is very useful in discriminating between checks and annuli.

The rostrum is also critical for an accurate identification of the fifth and subsequent annuli. With increasing age, herring otoliths accrete relatively little calcium on the posterior edge, although adequate deposition for annulus formation continues on the rostrum, which is the longest axis of the otolith (Fig. 9). Therefore, older herring otoliths may exhibit fewer annuli on the posterior edge relative to the rostrum; or annuli may be so closely spaced on this part of the otolith that it is difficult to distinguish them (Fig. 10). Occasionally, clustering of annuli on the posterior edge may result in underinterpretation of age relative to the rostrum (Fig. 11).

Annuli on the rostrum, however, are sometimes split into two (rarely more) hyaline zones (Fig. 12). Overinterpretation of age can be avoided by tracing each zone around the ventral edge of the rostrum. On this part of the otolith, the split zones reliably resolve into annuli. The second, third, and fourth annuli, however, must be carefully traced from the posterior edge of the otolith up to the rostrum, because the overgrowth of calcium on the rostrum may obscure these rings.

Growth patterns and/or morphology of herring otoliths do not appear to vary substantially in the Gulf of Maine area south to Cape Hatteras, except that adult herring otoliths from Georges Bank and south of Cape Cod exhibit somewhat more complex patterns. This greater complexity involves split, diffuse and somewhat less coherent annular zones and more prominent checks.

In summary, although current methodology has made the age determination of Atlantic herring relatively routine and reliable, misinterpretations can occur because of the formation of false annuli, checks, and split zones. Older herring otoliths should be interpreted with caution, using the rostrum and not the posterior edge of the otolith.

Citations

Anthony, V.C.
: **1972.** Population dynamics of the Atlantic herring in the Gulf of Maine. Unpubl. Ph.D. thesis, Univ. Wash., Seattle, 266 p.

Anthony, V.C., and G.T. Waring
: **1980.** The assessment and management of the Georges Bank herring fishery. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 177:72-111.

Bigelow, H.B., and W.C. Schroeder
: **1953.** Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53(74), 577 p.

Boyar, H.C., R.R. Marak, F.E. Perkins, and R.A. Clifford
: **1973.** Seasonal distribution and growth of larval herring (*Clupea harengus* L.) in the Georges Bank-Gulf of Maine area from 1962 to 1970. J. Cons. Int. Explor. Mer 35(1):36-51.

Dery, L., and J. Chenoweth
: **1979.** Recent problems in ageing sea herring from the Gulf of Maine. Ref. Doc. 79-38, Woods Hole Lab., Northeast Fish. Cent., Natl. Mar. Fish. Serv., Woods Hole, MA 02543, 7 p.

Einarsson, H.
: **1951.** Racial analyses of Icelandic herrings by means of the otolith. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 128:55-74.

Graham, J.J., B.J. Joule, C.L. Crosby, and D.W. Townsend
: **1984.** Characteristics of the Atlantic herring spawning population along the Maine coast inferred from larval studies. J. Northwest Atl. Fish. Sci. 5(2):131-142.

Hunt, J.J., L.S. Parsons, J.E. Watson, and G.H. Winters
: **1973.** Report of herring ageing workshop, St. Andrews, N.B., 11-13 December 1972. Res. Doc. 73/2, Int. Comm. Northwest Atl. Fish., Dartmouth, Nova Scotia, Canada B2Y 3Y9, 2 p.

Huntsman, A.G.
: **1919.** Growth of the young herring (so called sardines) of the Bay of Fundy. Dep. Naval Serv., Can. Fish. Exped. 1914-1915; p. 105-117.

International Passamaquoddy Fisheries Board
: **1960.** Passamaquoddy fisheries investigations, 1957-1958. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 360, 40 p.

Kornfield, I., B.D. Sidell, and P.S. Gagnon
: **1982.** Stock definition in Atlantic herring (*Clupea harengus harengus*): genetic evidence for discrete fall and spring spawning populations. Can. J. Fish. Aquat. Sci. 39:1610-1621.

Lea, L.
: **1919.** Age and growth of herring in Canadian waters. Dep. Naval Serv. Can. Fish. Exped. 1914-1915, 163 p.

Lissner, H.
: **1925.** Die altersbestimmung beim hering mit hilfe der otolithen. Ber. Dtsch. Wiss. Komm. Meeresforsch. 1:181-198.

Messieh, S.N.
1974. Problems of ageing Atlantic herring (*Clupea harengus harengus* L.) in the ICNAF area. Res. Doc. 74/59, Int. Comm. Northwest Atl. Fish., Dartmouth, Nova Scotia, Canada B2Y 3Y9, 6 p.

Messieh, S.N., and S.N. Tibbo
1970. A critique on the use of otoliths for ageing Gulf of St. Lawrence herring (*Clupea harengus* L.) J. Cons. Int. Explor. Mer 33(2):181-191.

Parsons, L.S., and G.H. Winters
1972. ICNAF herring otolith exchange 1971-1972. Res. Doc. 72/92, Int. Comm. Northwest Atl. Fish., Dartmouth, Nova Scotia, Canada B2Y 3Y9, 4 p.

Raitt, D.F.S.
1961. Otolith studies of southern North Sea herring. J. Cons. Perm. Int. Explor. Mer 26:312-328.

Scattergood, L.W.
1952. The maturity of the Maine herring (*Clupea harengus*). Maine Dep. Sea and Shore Fish., Res. Bull. 7, 11 p.

Sinclair, M., and T.D. Iles
1985. Atlantic herring (*Clupea harengus*) distributions in the Gulf of Maine-Scotian Shelf area in relation to oceanographic features. Can. J. Fish. Aquat. Sci. 42:880-887.

Watson, J.E.
1964. Determining the age of young herring from their otoliths. Trans. Am. Fish. Soc. 93:11-20.
1965. A technique for mounting and storing herring otoliths. Trans. Am. Fish. Soc. 94:267-268.

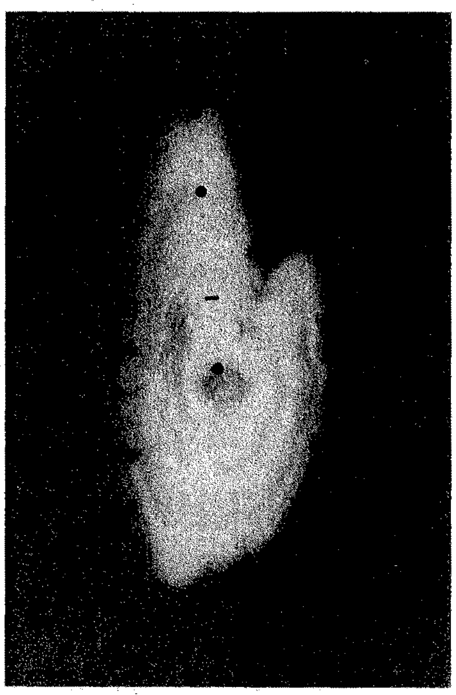

Figure 1
Whole embedded otolith of a 22-cm age-3 Atlantic herring collected in April showing a prominent first annulus and false annulus.

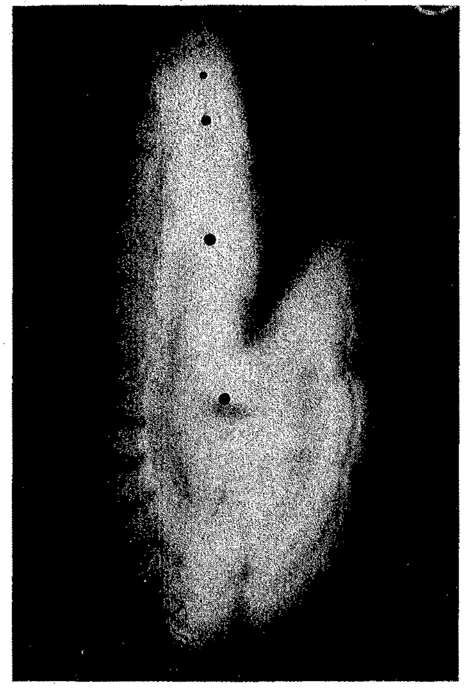

Figure 2
Whole embedded otolith of a 32-cm age-6 Atlantic herring collected in February showing hyaline edge. Second, third, and fourth annuli are weak on the rostrum; prominent checks on the postrostrum are difficult to distinguish from annuli.

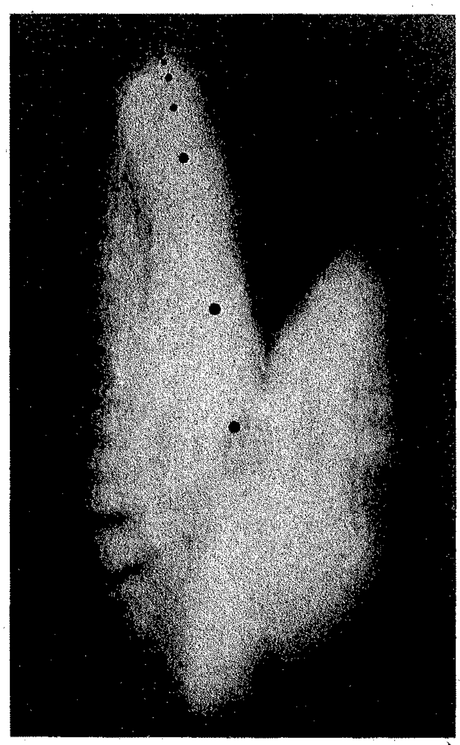

Figure 3
Whole embedded otolith of a 33-cm age 7+ Atlantic herring collected in October and showing hyaline edge. Annuli 2-5 are weak on the rostrum.

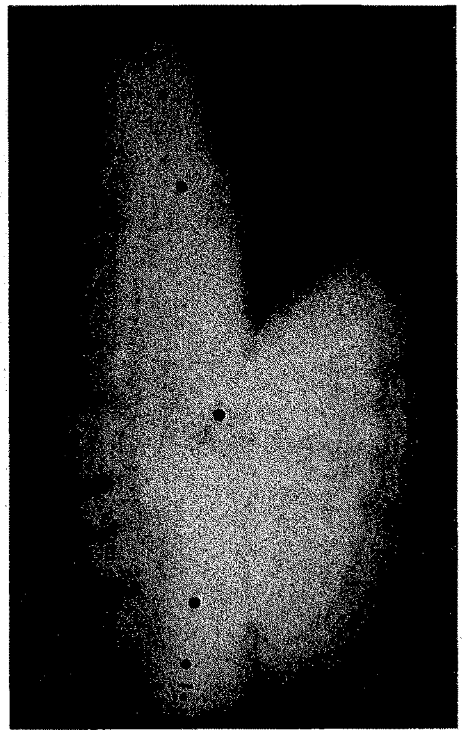

Figure 4
Whole embedded otolith of a 30-cm age-5 Atlantic herring collected in July and showing hyaline to narrow opaque edge. Strong checks are evident between the third and fourth, and fourth and fifth, annuli.

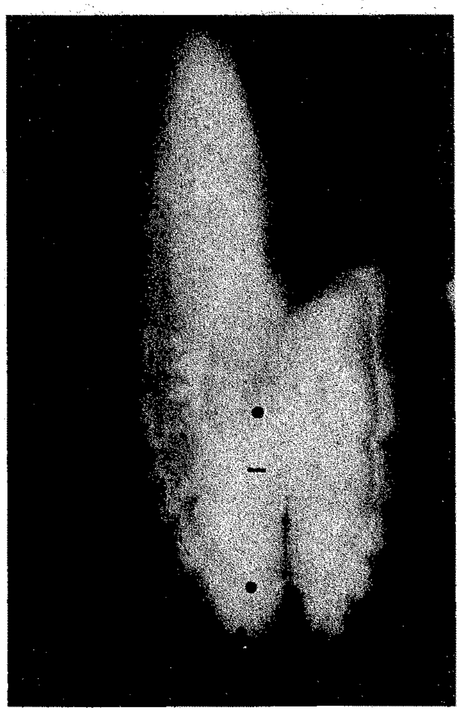

Figure 5
Whole embedded otolith of a 23-cm age-3 Atlantic herring collected in April showing a weak false annulus and large second annulus.

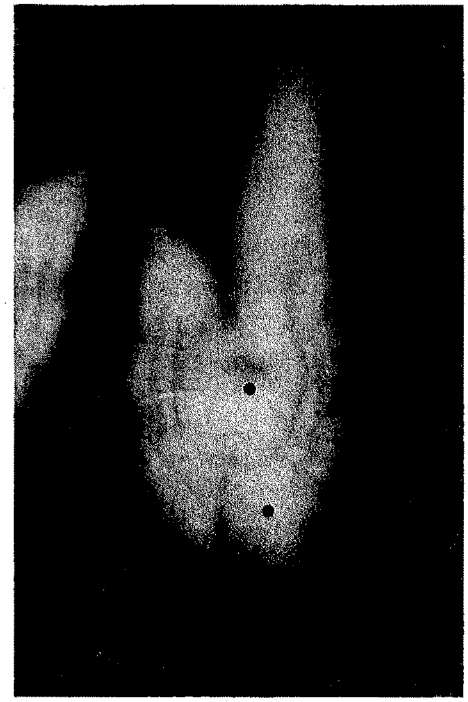

Figure 6
Whole embedded otolith of a 25-cm age-3 Atlantic herring collected in April showing a split second annulus.

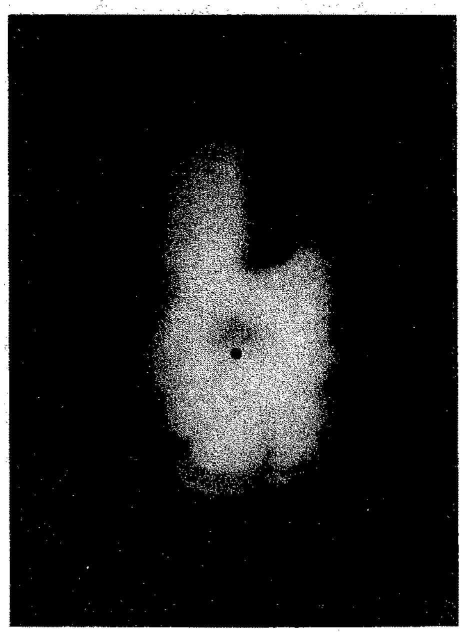

Figure 7
Whole embedded otolith of a 16-cm age 1+ Atlantic herring collected in September showing a split second annulus.

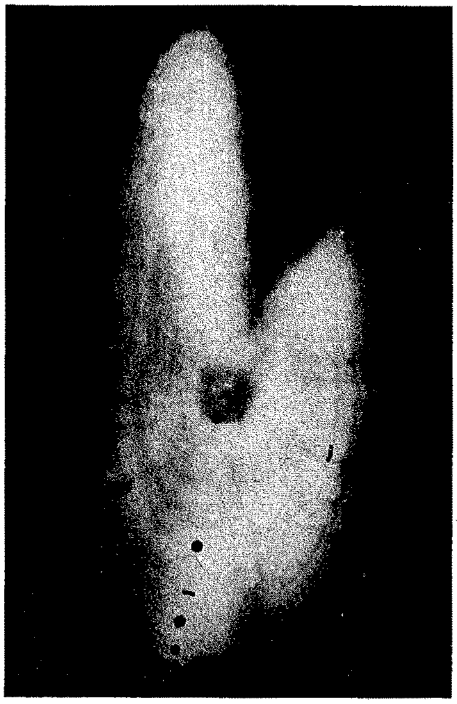

Figure 8
Whole embedded otolith of a 31-cm age 5+ Atlantic herring collected in October showing a weak check between the second and third annuli.

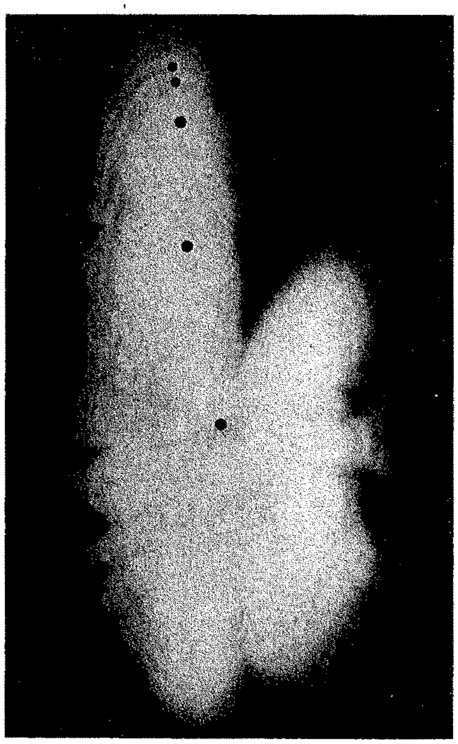

Figure 9
Whole embedded otolith of a 36-cm age-11 Atlantic herring collected in March showing clear annuli on the rostrum.

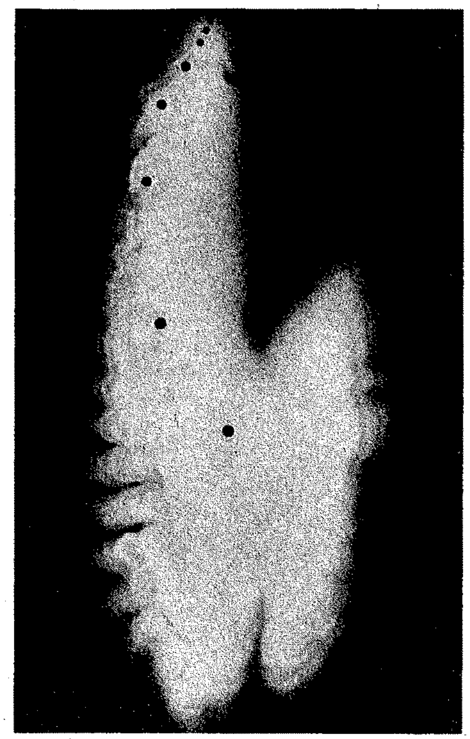

Figure 10
Whole embedded otolith of a 34-cm age-9 Atlantic herring collected in February. Weak second and third annuli on the rostrum; annuli compacted on the postrostrum.

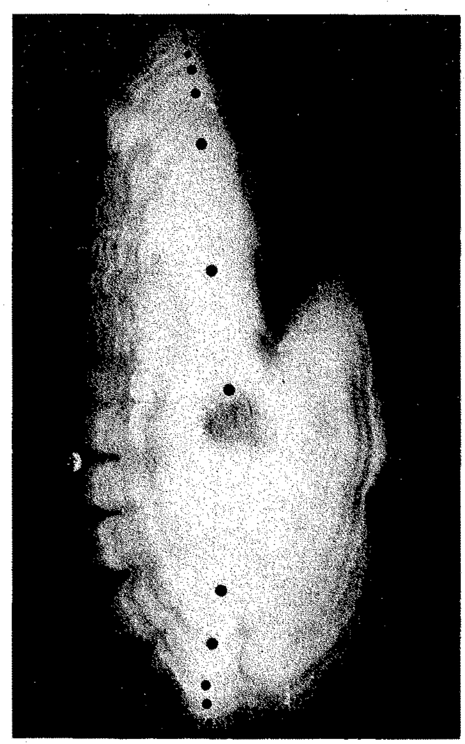

Figure 11
Whole embedded otolith of a 34-cm age-9 Atlantic herring collected in February showing nine annuli on the rostrum while only seven annuli are evident on the postrostrum.

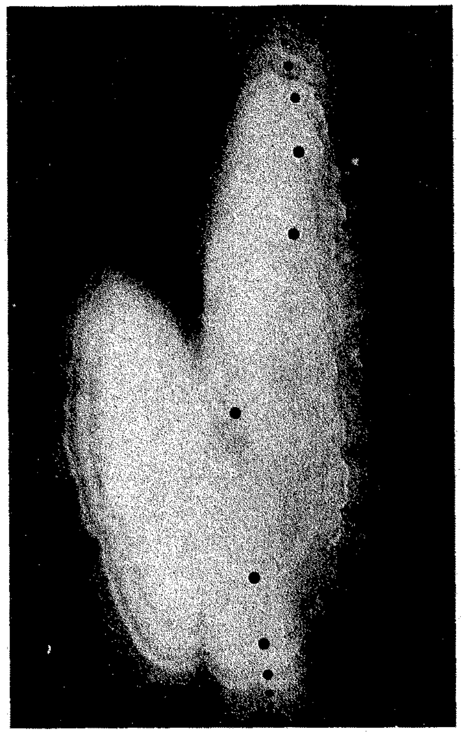

Figure 12
Whole embedded otolith of a 34-cm age-9 Atlantic herring collected in February showing split annuli on the rostrum and postrostrum.